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Visions for the Future of Housing **Mega Cities**

April 16-19, 2012 Istanbul Technical University

edited by

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New Constructive Solutions to Improve Energy Efficiency in Existing Buildings and Their Economic Viability

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Abstract

The improvement of energy efficiency in existing buildings is always a challenge due to their particular, and sometimes protected, constructive solutions. New constructive regulations in Spain leave a big undefined gap when a restoration is considered because they were developed for new buildings. However, rehabilitation is considered as an opportunity for many properties because it allows owners to obtain benefits from the use of the buildings. The current financial and housing crisis has turned society point of view to existing buildings and making them more efficient is one of the Spanish government's aims. The economic viability of a rehabilitation action should take all factors into account: both construction costs and the future operative costs of the building must be considered. Nevertheless, the application of these regulations in Spain is left to the designer's opinion and always under a subjective point of view.

With the research work described in this paper and with the help of some case-studies, the cost of adapting an existing building to the new constructive regulations will be studied and Energetic Efficiency will be evaluated depending on how the investment is recovered. The interest of the research is based on showing how new constructive solutions can achieve higher levels of efficiency in terms of energy, construction and economy and it will demonstrate that Life Cycle Costing analysis can be a mechanism to find the advantages and disadvantages of using these new constructive solutions. Therefore, this paper has the following objectives: analysing constructive solutions in existing buildings - to establish a process for assessing total life cycle costs (LCC) during the planning stages with consideration of future operating costs - to select the most advantageous operating system – To determine the return on investment in terms of construction costs based on new techniques, the achieved energy savings and investment payback periods.

1 Introduction. Efficiency assessment systems in rehabilitation actions

The current financial and real estate situation calls for a change in tendency and creates the need to seek new alternatives for a stock of buildings in need of significant retrofitting to keep being useful. Rehabilitation is a good opportunity for a large number of buildings, for its use and exploitation possibilities allow the investment to return within a safety margin. In this context and from the current legal framework, it is especially important to preserve developed real estate and make developers and owners responsible for keeping their properties in good design and use conditions. Both the Ley de Ordenación de la Edificación (Law on Administration of Building) and the Código Técnico de la Edificación (Technical Building Code) make a clear reference to the need of preserving buildings through good use and maintenance.

The economic viability analysis of a rehabilitation operation as an option to stop the building's abandonment and ruin implies that a cost is set for the investment. That figure does not only depend on the initial construction costs, but also on the future operation costs which will arise during the asset's new life cycle. As for the analysis of a building to be rehabilitated, production costs include those linked to the project stage (study and project) and the execution stage (construction costs and related construction expenses). Among working and exploitation expenses are energy consumption, maintenance operations and the possible rehabilitation or restoration. The cost of putting the building out into operation may coincide with its demolition cost if its useful life is elapsed, or with its sale or reuse if we analyse an intermediate period.

Despite it is not obligatory under the relevant regulations to assess energy performance in restoration and rehabilitation works, it is essential to take this information into account at the project stage. Some decisions may imply an increase in the construction costs, but they also imply long-term savings on the building's maintenance actions and its functioning. This comparison makes it possible to perform a comparative analysis of the possible advantages of using higher quality products, which are initially more expensive, as opposed to a less significant investment when it comes to subsequent costs. Energy expenses are to be significant during the building's life, so they must be assessed. Energy saving is actually directly related to a financial saving which should be promoted as a sustainability indicator. Comfort and safety levels demanded by the users grow higher every day, and a balance must be reached between service rendering, costs and the users' satisfaction.

Therefore, it is essential to come up with new assessment and appraisal systems using tools sufficiently integrated with quality models throughout the life of the building and all its elements [2]. ISO 15686-5 (Building and Constructed Assets) defines Life Cycle Costing (LCC) as a tool or technique to assess the total costs to arise during a specific cycle, including the stages of set-up, use and work, maintenance and loss of value in present use (and the subsequent disappearance of the system or element). Thanks to this method, decisions can be made during the rehabilitation project to optimise future costs and plan the conservation or maintenance budgets. Furthermore, it is at the same time helpful to choose between several alternatives, and it makes it easier to go for the most profitable option for the whole cycle [3]. The interest of this research lies on discovering whether new solutions in rehabilitations can reach higher efficiency levels from the energy, construction and financial point of view.

2 Spanish legal framework: current situation

The Código Técnico de Edificación (Technical Building Code) was passed on March 17, 2006 for the regulation of building processes as a consequence of the adaptation of the Spanish legal framework to European Directive 2002/91/EC, under which it is not obligatory to assess energy performance in actions carried out in protected buildings. This implied no changes with respect to the previous regulation, NBE CT-79, which limited its application to new constructions and used an extremely simple calculation method. In the future, the enforcement of European Directive 2009/28/EC will not imply significant changes in application areas.

However, the regulations in other European countries are much more restrictive and it is obligatory to assess energy performance in almost all kinds of buildings. They are only exempted from this obligation when it is clearly in conflict with protection, although alternative measures to keep minimum levels exist. Going back to the Spanish situation, the assessment is based on a variable reference method used for energy regulation and certification. This variable reference method is based on the comparison between the analysed building and another building which is identical at a geometric level but completely efficient [4] (Reference building). This method offers a comparative percentage between the actual and the ideal situation. Moreover, the energy certification obtained provides statistic data regarding the mean of buildings constructed in Spain. Several authors have claimed it is difficult to obtain good energy certifications if the design of the building is conservative, whereas it is easy for buildings with low energy efficiency.

3 Description of the case studies

Analysed case studies are two historic buildings with different degrees of protection located in the town of Orihuela, south of the Alicante province (Spain). The area's Mediterranean climate implies that the highest energy consumption in the year is made in summer, due to cooling systems. These two buildings have significant maintenance problems and a structure collapse process has started. In both cases, the intention is to change the use of the buildings to justify the high cost of rehabilitation.

Regarding their classification, these buildings may be considered to be efficient under the current regulations in Spain. They have few hollows, irregular geometry, the facade surface is small compared to the buildings' volume and their envelopes are solid and very thick. A preliminary analysis showed no significant energy losses. It should be easy to obtain a good energy certification by setting up a suitable inner conditioning system.

Given that those are rehabilitation works, the buildings may be exempt from the justification of energy performance under the current regulations. Nevertheless, in both cases the implementation of an outer isolation system that does not greatly affect the buildings' original appearance and guarantees the absence of significant cold bridges is taken into account. The amortisation of this isolation and the improvement in the building's heat performance justifies the investment to be made and discussed here.

3.1 Case 1. Ermita del Santo Sepulcro

Built in the mid XVIIth century and depending on the near Santa Clara convent, this small religious building was sold to a private client in 1976. Over time and without the minimum maintenance works, the building underwent a structure collapse process. It was bought by the Town Council of Orihuela, which started a reconstruction and rehabilitation process. Reconstruction was based on the recovery of two annex buildings that hooped the hermitage's nave and of the collapsed parts of the vault. Rehabilitation was focused on the areas of the building that survived the collapse: load-bearing walls, dome and part of the vaults.

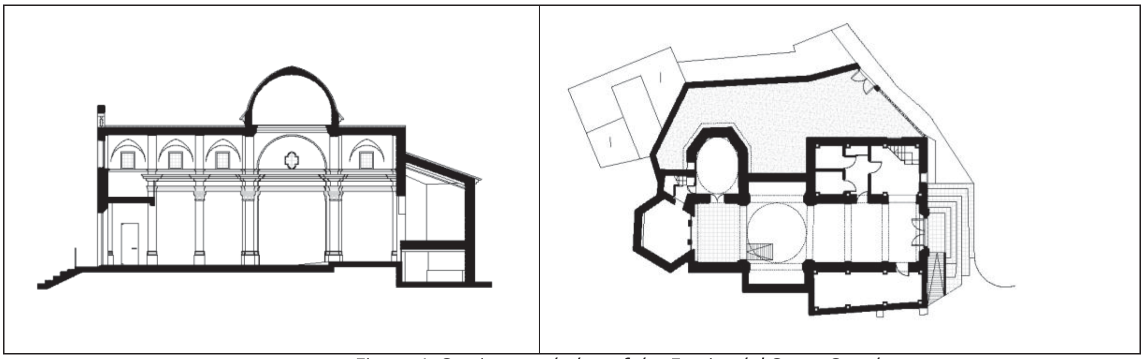

Figure 1: Sections and plan of the Ermita del Santo Sepulcro

Given that the building is no longer for religious use, in the future it will serve as a community centre for the quarter where it is located. The measures taken to ensure its right energy performance are based upon the setting up of an external isolation system and the design of conditioning systems to guarantee the users' comfort. The section type of the facade's finishes consists on the application of cement mortar with additives on a 5 cm-thick rock wool thermal insulation which is also used on the outer side of the hermitage's masonry load-bearing walls.

3.2 Case 2. Los Aljibes de Hurchillo

As in the case of the Ermita del Santo Sepulcro, the project arises from the collapse of the ancient underground water deposits as a consequence of changes in the environment. The cisterns were built in the XIXth century to bring water to the town of Hurchillo, in Orihuela. In this case, the challenge is to give this almost buried water structure a very different use. Rehabilitation works consist on reconstructing the vault of the collapsed cistern, reinforcing the remaining vault and constructing a new semi-buried building containing all the necessary services for the centre to work properly.

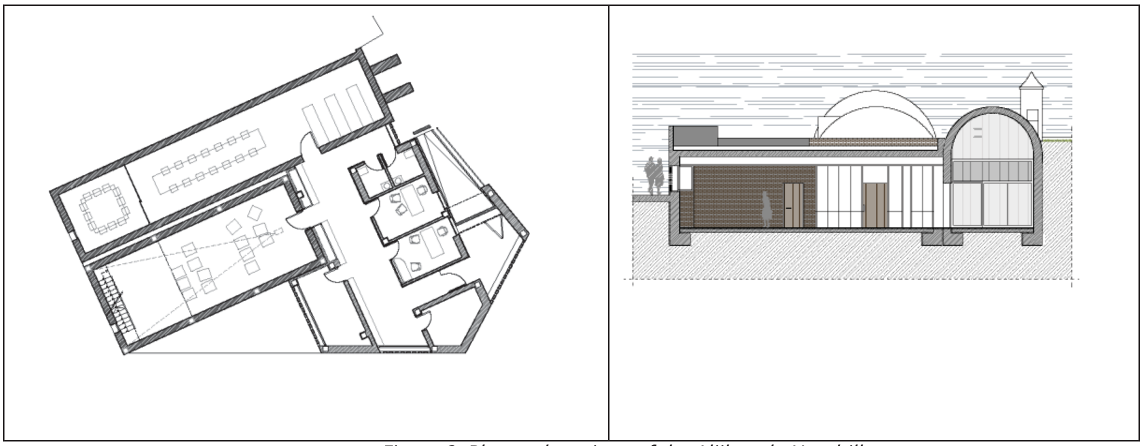

Figure 2: Plan and sections of the Aljibes de Hurchillo.

The section type of the facade's finishes consists on the application of cement mortar with additives on a 5 cm-thick rock wool thermal insulation. It is applied on the external part of the cisterns' load-bearing walls both in the still-standing area, made of 60-centimetre lime mortar, and in the reconstructed area, made of 40-centimetre thick concrete. The same treatment is applied on the original lime mortar vaults and on the reconstructed concrete vaults. In the new area, an external face brick sheet with continuous extruded polystyrene is placed.

4 Modelling

In both case-studies, modelling is made with the general method defined at CTE DB-HE using LIDER program. Securing of the energy certification is made through the program CALENER. The necessary details for the certification are obtained from the architecture program, both at a construction and at a hygrothermic conditioning level. With a view to knowing the improvements achieved with the application of the corrective measures aimed at obtaining a correct energy performance, the buildings are modelled twice. First, the on-going legal provisions are applied, and then they are excluded on the grounds of the buildings' protection. Now we will define the results arising from the modelling, taking into account that primary energy is that which has not underwent any transformations and final energy is the one used directly by consumers:

4.1 Case 1. The Ermita del Santo Sepulcro

The building's modelling using LIDER program shows the following results:

	With isolation		Without isolation	
	Heating	Cooling	Heating	Cooling
% of the Reference Building's demand	85.6	76.5	100.9	103.3
DIFFERENCE				
	Heating		Cooling	
% of the Reference Building's demand	15.3		26.8	

Table 1: Energy demand using Lider modelling. Ermita del Santo Sepulcro.

After the application of external isolation, the building's global transmittance is 15.3% lower in the winter and 26.8% in the summer. It is important to remember that the building is in the southeast of Spain, where energy consumption peaks in summer. With all these details and introducing those about inner conditioning, CALENER program (necessary to obtain the energy certification) gives the following results:

	With isolation		Without isolation	
	m2	Annual	m2	annual
Final energy consumption (kWh)	74.1	17,275.4	82.8	19,309.8
Primary energy consumption (kWh)	247.9	57,820.8	277.1	64,629.8
CO2 emissions (kgCO2)	72.7	16,946.8	81.2	18,929.5
DIFFERENCE				
	m2		annual	
Final energy consumption (kWh)	8.7		2,034.4	
Primary energy consumption (kWh)	29.2		6,809.0	
CO2 emissions (kgCO2)	8.5		1,982.7	

Table 2. Energy consumption. Ermita del Santo Sepulcro

If isolation is applied, letter B is awarded; if not, letter C is granted. Regarding the cost of applying these measures, it is important to know that the outer isolation system costs €61.05/m2 and the isolated facade area is 290.16 m2. The execution cost is 17,714.16 euro. The total cost of the building's rehabilitation works adds up to 362,177.64 euro.

4.2 Case 2. Los Aljibes de Hurchillo

The building's modelling using LIDER program shows the following results:

	With isolation		Without isolation	
	Heating	Cooling	Heating	Cooling
% of the Reference demand	87.5	74.6	103.7	104.5
DIFFERENCE				
	Heating		Cooling	
% of the Reference demand	16.2		29.9	

Table 3: Energy demand with Lider modelling. Aljibes de Hurchillo.

With the application of external isolation, the building's transmittance is 16.2% lower with heating and 29.9% lower when it comes to cooling. It is important to bear in mind that the building is at the south east of Spain, where energy consumption peaks in summer. With these results and including all the data on inner conditioning, CALENER program, essential to obtain the energy certification, has the following results:

	With isolation		Without isolation	
	m2	Annual	m2	Annual
Final energy consumption (kWh)	44.4	13759.6	52.2	16,159.1
Primary energy consumption (kWh)	148.7	46053.3	174.6	54,084.6
Co2 emissions (kgCO2)	43.6	13489.9	51.2	15,843.8
DIFFERENCE				
	m2		anual	
Final energy consumption (kWh)	7.8		2,399.5	
Primary energy consumption (kWh)	25.9		8,031.3	
Co2 emissions (kgCO2)	7.6		2,353.9	

Table 4: Energy consumption. Aljibes de Hurchillo.

If isolation is applied, B letter is awarded at the certification; otherwise, C is granted. With regards to the cost of these measures, the outer isolation system adds up to €61.05/m2, so with a total isolated facade of 354.92 m2 the execution cost is 21,667.86 euro. The total cost of the building's rehabilitation is 593,112.77 euro.

5 Financial assessment of the investment in the rehabilitated buildings

In order to carry out the financial assessment of the investment, a theoretical calculation model was applied. We used LCC analysis with a comparison of the different options and adopting a technical and economic viability point of view. A dynamic analysis where the value of the investment in the periods where the cash flow is produced is applied. The profitability of the investment will be established according to the construction costs, energy savings and recovery periods [1]. The dynamic analysis of the economic viability of the suggested solutions will try to prove how the current net value during the calculation period is higher than the investment made and that it is recommendable to use these kinds of solutions in rehabilitation works.

The research will also include the sum that would be saved annually if the proposed option was used instead of a reference solution. A reference solution is any traditional or already-existing solution as opposed to those suggested as an improvement. The financial assessment will also include a calculation of the risks that may determine the profitability variations expected from the investment [5]. The feasibility study will consider an initial investment equivalent to the financial cost of the intervention carried out to increase the thermal isolation of the external finishes of both buildings (€17,714.27 in case 1 and €21,887.86 in case 2), whose amount will be a cash flow to be recorded with a negative sign on the year the intervention is made. No other investments will be recorded during the life cycle of the heating, and neither will annual maintenance costs (cleaning of filters in inner elements and batteries in external units, checking of pressures) or the replacement of elements such as compressors and compensation fans). These operations would be necessary even if the intervention to improve the analysed building's energy efficiency had not been made. For the same reason, disassembly, waste management and recycling expenses at the end of the premise's life cycle (if applicable) will not be taken into account. Lower yearly maintenance costs that may arise from an eventual over performance of the equipment after the intervention will not be taken into account either, for they are considered to be too scarce.

As for revenue, energy savings generated by the intervention will be recorded as annual cash flows with a positive sign. In order to do so, the value of energy saving has been considered to be equivalent to the cost per kWh, this is €0.170783. Given that annual energy savings add up to 2034.4 kWh on case 1 and 2399.5 kWh on case 2, yearly income from this item would be €347.44 on case 1 and €409.79 on case 2. On the other hand, the differences in CO2 emissions as a consequence of the intervention have been recorded as revenue. For that purpose, the estimation made by Environment Watch (http://www.environment-watch.co.uk/co2.cgi) was used. Environment Watch estimates the cost of emissions produced by household electricity installations in Great Britain at 9.3 pence/kWh/year, this is 0.12 euro/kWh/year. Therefore, annual savings arising from the interventions are €250.23 on case 1 and €295.14. Thus, total annual revenue obtained as a consequence of the investment in the improvement of the finishing's thermal isolation thanks to the reduction of energy consumption and CO2 emissions is €597.67 on case 1 and 704.93 on case 2, which represents 3.37% and 3.22% on the investment made, respectively. In order to calculate the total revenue, the life cycle of the installed heating equipments has been set at 15 years, the usual period for these types of elements. Consequently, the investment recovery period (pay-back) is 30 years in case 1 and 31 years in case 2, thus the amortisation period is twice the life cycle of the heating system.

Once the yearly net cash flow is obtained by calculating the difference between the revenue and payments made during the operation (investment made on the first year plus revenue arising from the mentioned items on that same year and the following fourteen years), that sum is updated in order to take the money's current value into account. For that purpose, a V/(l+i)t formula will be applied, where V is the annual net value of the cash flows, t is each annual period included and i is the discount or interest rate applied.

The discount rate, which is equivalent to the profitability claimed by the developer in the intervention made, will be calculated as 3.5% yearly in real terms once the effect of inflation is discounted. The impact of the yearly increases in energy price on the revenue obtained thanks to a higher energy efficiency has not been taken into account. On this discount rate, the high risk-free rates existing in Spain at the time when this document is drafted are not taken into account, considering the current pressure of financial markets on public debt as a situational factor. Therefore, the net present value (NPV) obtained equals €-10,231.61 on case 1 and €-13,028.74 on case 2. These amounts represent the disproportionally high financial effort needed to improve the analysed energy performance.

6 Conclusions

Under the current Spanish regulations on evaluation and certification of the buildings' energy performance, it is not obligatory to carry them out on rehabilitation works. The methods to be applied at non-residential buildings (variable reference methods) penalise design-efficient buildings [4]. Ancient protected buildings, which fall into this category, usually have thick walls and are compact, with small glass-enclosed surfaces. Not many improvements can be made to these buildings by applying corrective measures to their energy performance and certification, and it is difficult to recover the investment. In this situation, the main issue is to decide whether the improvement of energy performance in ancient, protected buildings is a priority and if these kinds of investments can be profitable in the future.

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